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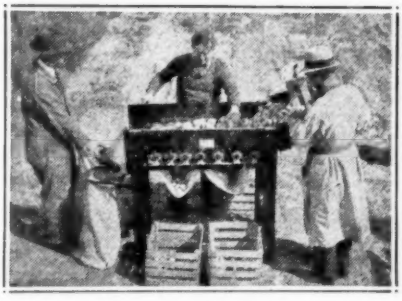

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THE RICHMOND MEETING

Present indications are that this will be one of the best attended meetings for several years since investigators interested in potato research from all sections of the country have expressed their intentions to present papers. Dr. F. A. Krantz will open the meeting with a report on "Twenty-five Years in the History of the Potato." Tentative plans are also being made for a cooking test demonstration at one of the sessions. It is anticipated that another session will be devoted to a discussion of the problems confronting the certification authorities. At this session arrangements are being made to discuss bacterial wilt, purple top wilt, hair sprout and other of the more recent diseases of the potato. This should be an important session since certain of these diseases have caused serious losses to potato growers.

The joint session with the American Society for Horticultural Science on Wednesday afternoon the 28th of December will be held in the Flemish Room of the Jefferson Hotel. The joint session with the American Phytopathological Society on Friday morning is scheduled to be held in the Business Men's Class Room of the Second Baptist Church. The regular sessions will be held in the Intermediate Department room on the second floor South of the Educational Building of the Second Baptist Church. The latter building and the Second Baptist Church are two different buildings but are in the same block. The Jefferson Hotel is less than a block from both these buildings.

The Jefferson Hotel is the official headquarters of the American Association as well as a number of affiliated societies. Other nearby hotels are the Murphy, Rueger and John Marshall. Foley F. Smith of the John Marshall Hotel is chairman of the Housing Bureau for the American Association and will assist in securing satisfactory accommodations. It would be advisable to make reservations at once since the attendance at the Richmond Meeting promises to be large.

MAGNESIUM STUDIES WITH THE POTATO[1]

Jos. A. Chucka, *Maine Agricultural Experiment Station, Orono, Me.,* and B. E. Brown, *Bureau of Plant Industry, United States Department of Agriculture, Washington, D. C.*

Much of interest has been written in recent years about the so-called uncommon, minor or secondary nutrient elements. No doubt scientific investigation will disclose much more of interest relative to these elements from a plant physiological standpoint, particularly with respect to their influence upon plant growth and production when used under widely varying soil conditions.

Among elements essential to plant life magnesium has proved to be of considerable interest in recent years. Although recognized as an important element, nevertheless no special interest was evinced in it from a plant nutrient standpoint because it was considered to be present in the soil in sufficient amount for normal crop growth. Magnesium was therefore generally accepted as an essential element to plant life but with no reason to feel that a shortage of available magnesium, except perhaps under unusual soil conditions, was other than highly problematical.

Magnesium Deficiency in Soil More Prevalent in Recent Years

In recent years, however, the question of the value of magnesium in potato production has attracted considerable attention in a number of commercial potato-producing states along the Atlantic Seaboard including Maine, Massachusetts, Connecticut, Rhode Island, North Carolina, and South Carolina. Studies both in the United States and in Europe tend to confirm that magnesium deficiency may readily ensue under certain soil conditions. The consensus of opinion gained through actual field trials and through observation is that the primary factors instrumental in bringing about a deficiency of available magnesium in the soil include the following: (1) Excessive soil acidity, (2) heavy applications of acid-forming fertilizer low in magnesium to land already too acid, (3) too low an organic matter content which permits a more intensive acidity effect, (4) leaching effect of prolonged rainfall on available magnesium, (5) soil not adaptable to potatoes such as soil too sandy, soil too readily leached of nutrient materials or

[1]Cooperative project conducted by the Maine Agricultural Experiment Station and the Division of Soil Fertility Investigations, Bureau of Plant Industry, U. S. Department of Agriculture.

soil containing insufficient magnesium, and (6) thin, easily eroded land.

A shortage of this element has been found to depress chlorophyll formation in potato and other plants as a result of which the normally integrated processes of metabolism are retarded to the extent that growth is stunted and yields correspondingly reduced. Not only is there a marked curtailment of foliage growth but root development is also restricted to such an extent that the opportunity for magnesium absorption is reduced accordingly. Additional symptoms noted with respect to the potato plant in Aroostook County are as follows: Instead of the normal dark green color the leaves of the affected plants were chlorotic. The loss of green color began at the tips and margins of the lowermost leaves of the plant and progressed between the veins toward the center of the leaves. In more severe cases nearly the entire area of the leaves and all excepting the tip of the plant were affected. The leaves showed a definite bulging between the veins and became thick and somewhat brittle. In advanced stages the chlorotic leaves died, turned brown, and often dropped off the plant. Affected foliage was found to contain much less magnesium than normal foliage.

EXPERIMENTAL STUDIES WITH MAGNESIUM IN AROOSTOOK COUNTY

The first signs of what later proved to be a deficiency of magnesium in Aroostook County potato soils showed up some ten or twelve years ago. At first only scattered areas within fields were involved, later the trouble designated "potato sickness" by growers, became progressively worse. In 1929 a survey of conditions associated with the trouble suggested a possible deficiency of one of the nutrient elements. This led to the establishment of experimental work at the Aroostook Experiment Farm at Presque Isle, Maine, and with a number of commercial potato growers. Preliminary experimental work in 1930 indicated that the lacking element might be magnesium, an indication amply confirmed by studies over a period of several years following. The present paper presents a brief review of the experimental findings and how the problem of magnesium shortage in Aroostook County potato soils was solved to the satisfaction of all interests concerned.

RESULTS OF MAGNESIUM STUDIES IN 1930

Preliminary studies in 1930, comparing fertilizer with and without added magnesium on two farms showed that the addition of about 300 pounds of ordinary Epsom salts, per ton of 4-8-7 fertilizer, not only insured normal foliage and vine growth, but also increased the yield

by an average of about 56 barrels per acre for the two locations. It is well to state that potatoes grown previously on both of the farms selected for the 1930 study had shown the trouble very badly. The significance of this result was the more striking because of the abnormal appearance of so many potato fields that season and because growers, fertilizer manufacturers and fertilizer salesmen were much disturbed as to the cause.

Results for 1931

Following the striking lead obtained in 1930 the experimental studies were expanded to include different sources and rates of magnesium on three farms representative of typical potato soil in Aroostook County. The magnesium materials used were Epsom salts, double sulphate of potash-magnesia and hydrated dolomite. Since previous readings had shown that the soils in the affected areas were strongly acid it seemed advisable to determine the effect alone of curtailing the acidity in these soils. In order to do so, ground limestone (practically free from magnesium) was used at the rate of 1000 pounds to the acre in the row added with fertilizer with and without magnesium. Field observations during the growing season of 1931 again indicated that magnesium completely prevented the chlorotic appearance of the potato plants. The yields obtained from the various treatments are recorded in table 1. All treatments were replicated four times on each farm and the results presented are averages of the four replications.

In connection with table 1 it will be noted that all of the magnesium-treated plots gave somewhat higher yields than those which did not receive magnesium. The lower magnesium applications seemed to be more effective than the higher, indicating that the larger quantities of magnesium may have resulted in magnesium toxicity to some extent. This seems to be substantiated by the fact that when lime was used with magnesium the higher applications were nearly as effective as the lower applications. The results also indicated that larger quantities of magnesium oxide may be used in the form of the double sulfate of potash-magnesia than in the form of Epsom salts. The comparatively low yields obtained with the use of dolomite may have been caused by the excess quantity applied, due to the quantity applied having been excessive. When calcium limestone without magnesium was used with the fertilizer the yields were slightly lowered. This may have been caused in part by the depressing effect of lime on the solubility of the magnesium naturally present in Aroostook potato soils, chiefly the Caribou loam.

In addition to the inclusion of magnesium sources in potato fer-

TABLE 1.—*Results with magnesium in potato fertilizers*—1931

Treatment	Pounds MgO Per Acre	Yields in Bushels Per Acre				Increase over Check Bushels Per Acre
		Daigle Farm	Libby Farm	Bradford Farm	Average of Three Farms	
Check[1]	0	326.2	368.8	386.1	360.4	
Check + 100# $MgSO_4 . 7H_2O$	17	345.7	399.9	405.9	383.8	+ 23.4
Check + 300# $MgSO_4 . 7H_2O$	51	339.9	396.8	370.7	369.1	+ 8.7
Check + 500# $MgSO_4 . 7H_2O$	85	326.4	391.6	379.2	365.7	+ 5.3
2000# 4-8-7[2]	55	342.4	426.8	405.9	391.7	+ 31.3
2000# 4-8-10[2]	78	367.4	405.6	416.6	396.5	+ 36.1
Check + lime[3]	0	323.4	363.6	381.4	356.1	
Check + 100# $MgSO_4 . 7H_2O$ + lime	17	358.9	397.9	391.6	382.8	+ 26.7
Check + 300# $MgSO_4 . 7H_2O$ + lime	51	349.8	392.2	392.4	378.1	+ 22.0
Check + 500# $MgSO_4 . 7H_2O$ + lime	85	353.9	399.3	377.0	376.7	+ 20.6
Check + 500# hydrated dolomite	150	346.2	379.2	377.6	367.7	+ 11.6
Check + 1000# hydrated dolomite	300	328.4	341.0	408.4	359.3	+ 3.2

[1]Check consisted of 2000 pounds per acre of 4-8-7.

[2]Seven and ten units of potash were made up by using double sulfate of potash-magnesia.

[3]Lime refers to ground limestone applied separately in the potato row at the rate of 1000 pounds per acre.

tilizers in the experimental work, magnesium was used by commercial growers on approximately 200 acres of potatoes in Aroostook County during 1931. Where comparative yields were taken in these commercial fields the results indicated an average increase of approximately 44 bushels on each acre in favor of the fertilizer carrying magnesium. In two commercial fields, after the potato plants had developed very definite symptoms of the disease, magnesium sulphate was applied as a side dressing to a depth of approximately two inches between the plants in the row at the rate of 320 pounds to the acre. Observation

of these areas during the remainder of the growing season indicated that although the chlorotic tissues did not regain their green color, nevertheless all the subsequent new growth had a normal dark green color and the plants in the treated areas made a greater total growth than those to which magnesium was not applied.

A marked residual effect of the magnesium used in the row on potatoes in 1930 was observed on oats and clover in 1931. The oats and clover growing on the rows where the potato fertilizer was applied were fully twice as large as compared with the in-between-the-row areas. This observation indicated that other crops, as well as potatoes, were hampered from a lack of magnesium under certain soil conditions in Aroostook County.

Results for 1932

In 1932, a fertilizer mixture containing additions of 10, 20, 30, and 60 pounds of magnesium oxide (MgO) from ordinary Epsom salts, double sulphate of potash-magnesia and dolomitic limestone were compared with similar fertilizer containing no added magnesium. The experimental work in 1932 was carried out on five farms selected so as to represent a wide range in productivity. The results obtained in 1932 are presented in table 2.

Table 2.—*Effect of magnesium in potato fertilizers on five farms varying greatly in productivity*—1932

Treatment	Yield of Check Treatment and Increases Due to Magnesium (Bushels per Acre)				
	Farm 1	Farm 2	Farm 3	Farm 4	Farm 5
Check (2000# 4-8-7)	211	247	308	404	484
Check + Epsom salts	260 (+49)	273 (+26)	343 (+35)	416 (+12)	467 (−17)
Check + Sulfate potash-magnesia	279 (+68)	268 (+21)	(+ 9)	(+13)	481 (− 3)
Check + Dolomitic limestone	255 (+44)	265 (+18)	308 (+ 0)	412 (+ 8)	473 (−11)
Average	265 (+54)	272 (+25)	323 (+15)	415 (+11)	474 (−10)

The yields for the three magnesium sources represent the average effect of 10, 20, 30, and 60 pounds of added magnesium oxide from each of the above sources of magnesium. The figures in parenthesis underneath the yield figures represent (increases or decreases over the check treatment) the average effect of all rates of magnesium applications.

An examination of the yields given in table 2 indicates clearly that the farms on which the tests were conducted did represent a wide range in productivity, namely, 211 to 484 bushels on each acre. Considering the average yields for the five farms, the increase in yields due to additions of magnesium ranged from 2 to 29 bushels to the acre. Considering instead the results obtained for individual farms it will be noted that the response to added magnesium was distinctly positive on four of the five farms and negative on the fifth where the highest yields were obtained.

RESULTS IN 1933

In 1933, fertilizers containing additions of 0, 10, 20, 30, and 60 pounds of magnesium oxide from Epsom salts, double sulfate of potash-magnesia and dolomitic limestone were again compared on five different farms in Aroostook County. Considering the average yields obtained on ten farms for 1932 and 1933 the increases in yield caused by the magnesium ranged from 3 to 23 bushels on each acre. The average results for ten farms for the two year period, 1932-1933 are presented in table 3.

TABLE 3.—*Results with different amounts of magnesium (positive or negative) in potato fertilizers*

Average Results on Ten Farms. 1932-1933

Source of MgO	Amount of MgO and Its Effect			
	10 lbs.	20 lbs.	30 lbs.	60 lbs.
	(Bushels per Acre)			
Epsom salts	+12	+15	+20	+20
Sulfate potash-magnesia	+18	+17	+22	+23
Dolomitic limestone	+ 7	+ 3	+18	+11
High-calcium limestone[1]	—18	— 5	—11	—13

[1]High-calcium limestone contained only a trace of magnesium. The amounts of it used were the same as the amounts of 20 per cent dolomitic limestone necessary to furnish 10, 20, 30, and 60 pounds respectively of magnesium oxide. It was not added as a source of magnesium but merely to compare its effect with that of equal quantities of dolomitic limestone. In practically all tests the effect of high-calcium limestone was to depress yields.

TABLE 4.—*The effect of equal quantities of magnesium from different sources on potato yields*

Average Results on Ten Farms. 1932-1933

Treatment	Acre Yield (Bushels per Acre)	Increase or Decrease (Bushels per Acre)
Check (2000# 4-8-7)	389	....
Check + Epsom salts	406	+17
Check + Sulfate potash-magnesia	409	+20
Check + Dolomitic limestone	399	+10
Check + High-calcium limestone[1]	377	—12

[1]High-calcium limestone contained only a trace of magnesium. The amounts of it used were the same as the amounts of 20 per cent dolomitic limestone necessary to furnish 10, 20, 30 and 60 pounds respectively of magnesium oxide. It was not added as a source of magnesium but merely to compare its effect with that of equal quantities of dolomitic limestone. A depression in yield resulted from its use. The various materials compared were added to the normal 4-8-7 fertilizer.

APPLYING MAGNESIUM AFTER THE DEVELOPMENT OF MAGNESIUM DEFICIENCY SYMPTOMS

Because many growers had inquired as to whether it would be advisable to apply magnesium compounds after the plants had emerged and magnesium deficiency symptoms had become evident, experimental work was conducted on 5 farms in 1932 and 1933 to answer this question. The magnesium sources compared were ordinary Epsom salts and sulphate of potash-magnesia. Applications were made during the first week in July approximately at the budding stage. Uniformly affected areas were selected and half of each area was treated with magnesium from the different sources, the remaining half left untreated. Such treatment would be in addition to fertilizer, usually at the rate of 2000 pounds to the acre, at planting time. In all the side-dressing tests noticeable response to the added magnesium was observed within five to ten days after the magnesium was applied. Although the treatments failed to impart a green color to the potato foliage already chlorotic they did prevent new foliage from developing chlorosis. It was also observed later that untreated plants died prematurely while the plants treated with magnesium remained green until killed by frost.

In addition to side-dressing the potato plants with magnesium compounds after the plants were up, the effect of adding a soluble magnesium compound, (magnesium sulphate), to the spray mixture was tried. The total amount of magnesium sulphate so applied throughout the spraying season, involving 6 sprayings, amounted to 60 pounds. Even so small a quantity of magnesium was effective within five days after the first spraying in conjunction with Bordeaux mixture. This rapid, as well as marked response, to magnesium applied on the potato foliage indicates that there was probably a direct absorption of the deficient element through the leaves rather than that the magnesium sulphate was washed into the soil and absorbed by the roots.

Results showing the comparative effectiveness of magnesium sulphate when applied to the soil as a top dressing and dissolved in the spray mixture are presented in table 5.

TABLE 5.—*Effect of magnesium compounds applied as a side dressing to the soil and in the spray mixture to potato plants after severe magnesium deficiency symptoms had developed*

Farm	Year	Treatment	Check Yield[1] (Bus. per Acre)	Yield from Plots Treated with Magnesium (Bus. per Acre)	Increase over Check (Bus. per Acre)
Daigle	1932	320 lbs. Epsom salts	259	396	137
Daigle	1932	320 lbs. Sulfate potash-magnesia	223	355	132
Bradstreet	1933	320 lbs. Epsom salts	276	328	52
Woodman	1933	320 lbs. Epsom salts	190	350	151
Woodman	1933	60 lbs. Epsom salts sprayed on[2]	224	363	139

[1]Check yield refers to yield from plots to which magnesium was not applied after plants had emerged.

[2]Ten pounds of Epsom salts to the acre sprayed six times on potato plants with Bordeaux mixture. All other treatments applied as top dressing to the soil. A 4-8-7 fertilizer mixture, 2000 lbs. to each acre, applied at time of planting without extra magnesium being included.

The magnesium studies so far reported show that under certain soil conditions magnesium became deficient enough in Aroostook County potato soils to cause considerable damage to the potato crop. These studies also showed the remedy for the trouble and as a result practically all fertilizer now used in Aroostook County contains magnesium in some form. It is of interest to further note that although any number of magnesium-deficient potato fields were in evidence during the early outbreak, yet by 1934, perhaps earlier, it was a hard matter to locate a potato field showing definite signs of magnesium deficiency. Following the recommendations made to fertilizer manufacturers, relative to the use of magnesium just as soon as the cause of the trouble was determined, there ensued a fairly general incorporation of magnesium in potato fertilizers. In addition, there developed an increasing use of dolomitic limestone and in connection with the spraying program dolomitic hydrate was utilized on account of its magnesium content. These treatments have no doubt tended to build up a reserve of magnesium in the soil. The remedies proposed are, however, both economical and practical and insure that magnesium deficiency no longer constitutes a soil fertility problem in Aroostook County.

Further Magnesium Studies, 1934-1937

In 1934, further experiments were started in order to determine: (1) whether incorporating dolomitic limestone with potato fertilizer would be of any advantage as a means of counteracting any potential acidity of the potato fertilizer; (2) whether magnesium added to the fertilizer would continue to give increased yields; (3) whether magnesium added to fertilizer would influence potash intake; (4) and whether the addition of magnesium to the fertilizer would materially modify the composition of potato foliage, collected periodically in the growing season, with respect to nitrogen, phosphorus, calcium, magnesium and potassium.

Concerning the effect of adding dolomitic limestone to the fertilizer it may be stated briefly that for the four year period the acid fertilizer has given just as high yields, sometimes greater, than the fertilizer containing sufficient dolomitic limestone to offset the potential acidity of the fertilizer.

Results obtained subsequent to 1933, comparing the effect of fertilizer with and without magnesium, are given in table 6.

Concerning whether the addition of magnesium to potato fertilizer would continue to give increased yields it will be noted that in 1934 the

TABLE 6.—*Effect of adding magnesium*[1] *to potato fertilizer during succeeding crop seasons of* 1934-1937

Treatment	Results for 1934		Results for 1935		Results for 1936		Results for 1937	
	Emery Farm	Higgins Farm	Emery Farm	Higgins Farm	Emery Farm	Higgins Farm	Emery Farm	Higgins Farm
	Bus. per Acre	Bus. per Acre	Bus. per Acre	Bus. per Acre	Bus. per Acre	Bus. per Acre	Bus. per Acre	Bus. per Acre
Magnesium added to fertilizer	391	458	466	272	487	369	373	424
No magnesium added to fertilizer	356	441	413	264	451	360	374	431
Difference ± for magnesium	+35	+17	+55	+8	+36	+6	−1	−7

[1]Added as magnesium sulphate (Kieserite).

fertilizer mixtures containing magnesium gave an average yield of 391 bushels to the acre, and without magnesium 356 bushels, a difference of 35 bushels in favor of magnesium in the fertilizer. The variety grown was Green Mountain.[1] At another location,[2] growing Irish Cobbler variey, the average yield for the fertilizer to which magnesium was added was 458 bushels on each acre; without magnesium 441 bushels, a difference of 17 bushels to the acre in favor of magnesium fertilizer. Continuing the comparison, in 1935 the addition of magnesium gave increases, although not very marked in one of the tests. In 1936 magnesium added with the fertilizer gave increased yields, although slight in one case. In 1937 slight yield decreases were registered for the fertilizer to which magnesium was added. The latter result suggests that although a certain amount of variation is liable to occur from farm to farm the main interest centers in the greater response of the Green Mountain variety to magnesium than is shown by the Irish Cobbler. By 1937, however, the response to magnesium on the part of both varieties was a shade less in the case of the magnesium-containing fertilizer, suggesting that, in time, no increase in yield necessarily is to be expected from adding magnesium to the fertilizer. The important thing accomplished is that, by adding the magnesium, the potato grower is definitely insured against any lack of magnesium during the growing season.

[1]Emery farm.
[2]Higgins farm.

With reference to studies to determine the influence of magnesium when added to fertilizer on potash intake, and on the composition of potato foliage, periodically collected, it is felt desirable that they progress further before attempting to present the data.

Summary

The element magnesium is a component of the chlorophyll molecule, and when deficient in the soil, chlorosis ensues because of disturbed growth processes. In Maine, chiefly in Aroostook County, about 10 to 12 years ago a so-called "potato sickness" developed which was later shown to be caused specifically by lack of magnesium in the soil. This was conclusively shown by experimental work running over a period of several years. For example, in 1930, fertilizer to which magnesium sulphate was added gave an average increase for two farms of 56 barrels to the acre over the same kind and quantity of fertilizer without the magnesium. Subsequent trials for a period of several years, in which different magnesium compounds were compared, simply add emphasis to the importance of magnesium in potato production.

Approximately 25 pounds of magnesium oxide, equivalent to about 150 pounds of ordinary Epsom salts or 75 pounds of the anhydrous salt, to the acre, will amply take care of the magnesium requirement of the potato crop in Aroostook County. Other magnesium compounds, such as sulphate of potash-magnesia, and calcined Kieserite, have proved equally effective.

Dolomitic limestone, when mixed with the fertilizer helped considerably but when there is a shortage of available magnesium it was found best to depend upon a soluble source of magnesium. Dolomitic limestone serves its best purpose when applied broadcast to tone down soil acidity and help build up a reserve of magnesium in the soil.

The use of high calcium limestone in potato fertilizer is not to be recommended even to offset fertilizer acidity. In practically all cases the use of this material in fertilizer depressed the yield.

Material increases in potato yields were obtained by the addition of soluble magnesium (the sulphate) as a top-dressing or in the spray mixture, particularly in potato fields where severe magnesium deficiency symptoms developed soon after the plants had emerged from the ground.

In conclusion, the magnesium-deficiency problem relating to the potato crop in Aroostook County was solved in such a way that both a practical and economical remedy could be recommended. It is

probably true that there is very little potato fertilizer being used in Aroostook County that does not contain added magnesium. The cost of the added magnesium to the grower is many times compensated by the fact that it enables him to maintain the productivity of his soil at a much higher level than if he were contending with magnesium deficiency.

BACTERIAL WILT AND ROT OF POTATOES—SOME SUGGESTIONS FOR ITS DETECTION, VERIFICATION, AND CONTROL[1]

H. N. RACICOT[2], D. B. O. SAVILE[3], AND I. L. CONNERS[2]

Central Experimental Farm, Ottawa, Canada

Bacterial wilt and rot of potatoes is a comparatively new, but serious disease. It has already been shown that it is caused by an organism closely related to both *Phytomonas michiganensis* (E. F. S.) Bergey *et al.*, the cause of bacterial canker of tomatoes, and *Phytomonas sepedonica* (Spiekermann) Savile and Racicot, the cause of bacterial ring rot of potatoes in Germany (1). The disease appears to be spreading, but its geographical distribution is not completely known; so far it has been reported in widely scattered localities in North America. The discovery of this disease here and there in areas previously thought to be free from it, makes it imperative that every one, pathologist, inspector, and grower, should keep a sharp lookout for it. It has already caused serious losses to growers, and threatens further losses unless it is successfully controlled.

SYMPTOMS

The symptoms appear generally late in the growing season, are very variable, and frequently resemble those of other diseases. The most characteristic ones are here described in the order in which they usually occur. The first symptom is a rolling of the leaflets on affected stems (Fig. 1), and is similar to that seen on healthy plants during hot, dry weather. The affected leaflets soon wilt, lose their normal color, and become a dull green. They then feel thin and soft to the touch. The affected leaflets partly or wholly turn yellow, and the chlorotic areas

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[1]Contribution No. 563 from the Division of Botany and Plant Pathology, Science Service, Department of Agriculture, Ottawa, Canada.

[2]Plant Pathologist.

[3]Graduate Assistant.

FIGURE 1

DISEASED PLANT ON THE LEFT AND HEALTHY PLANT ON THE RIGHT.
NOTE THE STUNTING, LEAFROLLING AND CHARACTERISTIC TYPE OF WILTING.

FIGURE 2

INFECTED OVER-WINTERED TUBER CUT LENGTHWISE.

THE ROT IS SEVERE AT THE STOLON END AND SLIGHT AT THE EYE END.

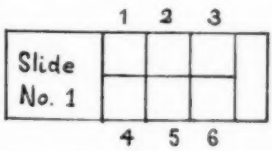

FIGURE 3

DIAGRAM OF RULED SLIDE FOR MAKING SMEARS FROM POTATO STEMS AND TUBERS.

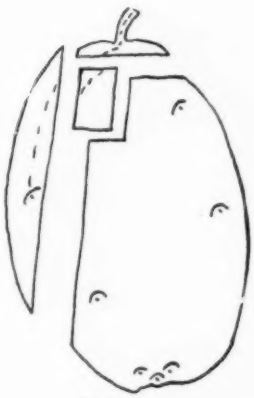

FIGURE 4

DIAGRAM ILLUSTRATING HOW A TUBER MAY BE CUT FOR MAKING SMEARS.

soon die. This necrosis or leaf scorching is chiefly at the margins of the leaflets, and resembles late blight, but it is confined to the leaves of individual stems, whereas late blight affects all plants about equally. The ends of the leaf stalks of affected leaves wilt, while the basal parts remain rigid. This resembles tarnished plant bug injury, but in the case of wilt there is no visible injury to the midrib. Eventually the entire leaf dies. One or more stems in a hill may wilt, while the others remain apparently healthy. The stems that wilt are more or less stunted.

When a plant, with visible symptoms of wilt, is dug, some of the tubers are usually badly diseased, there being, as a rule, every gradation from sound to completely decayed tubers. The bacteria enter the tubers through the stolon and spread along the vascular ring, causing in that region a rot which is creamy, yellow, or light brown in color, crumbly or cheesy, and odorless (Figure 2). It does not resemble what is generally called "net necrosis", although it is possible for both bacterial wilt and rot and net necrosis to occur in the same tuber. When the bacteria have spread through the tuber to an eye or eyes, the tissues in that region are often killed, rendering the tuber liable to invasion by soft-rotting organisms. Indeed, many of the tubers are invaded in this manner. The epidermis of badly rotted tubers may become cracked or show reddish discolored areas. In diseased tubers that have escaped invasion by secondary organisms, the rot may become sufficiently advanced to show as a band of decay involving the vascular ring and adjacent tissues.

OVERWINTERING AND DISSEMINATION

The most important way in which the bacteria overwinter is in slightly affected tubers, some of which may show no signs of the disease in the spring. Diseased tubers will contaminate the knife and planter, and they in turn will inoculate healthy sets. It has been found that the knife is a very efficient agent in the transmission of the disease.

Moreover it is suspected that bacteria from decayed tubers smeared on the surface of healthy tubers, may remain alive all winter in the dry state, and infect the sets when the tubers are cut.

It has yet to be determined whether or not the bacteria that are free in the soil can remain alive and virulent all winter. However, volunteer plants growing from diseased tubers, which have over-wintered in the soil, have developed the disease.

When diseased or newly inoculated sets are planted, the bacteria spread along the vascular bundles into the shoots, and eventually pass

through the stolons into the new tubers. There is apparently very little spread of the disease in the field.

Control

The chief means of control, and the only one recommended so far, is the exclusive use of disease-free seed. Certified seed potatoes are the only kind that can be recommended. Such seed should not be planted in soil where the disease has occurred the previous year.

The selection of sound tubers for seed from an affected crop is not considered practical. Some slightly affected tubers appear perfectly sound even in the spring. Moreover, no matter how few diseased plants have been found in a field, the estimated amount of disease from plant inspection has been invariably too low. Therefore, a crop in which only a trace of the disease is found should, under no circumstances, be used for seed. All of the tubers from a diseased crop should be disposed of preferably by cooking and feeding to live-stock, or for making starch.

The treatment of cut sets with organic mercury disinfectants may reduce the disease, and therefore prove of value to the table stock grower who has bought the best seed available, but in which an undetected small amount of bacterial wilt and rot is present. However, experiments to verify this must be conducted before definite recommendations can be made. Seed treatment cannot be recommended to the certified seed grower to control this disease, unless it is to prevent chance infection from some outside source such as bags, bins, etc. Any lot of tubers in which even a trace of the disease is found should not be used for seed.

Where the disease has occurred on a farm, the storage warehouse or cellar, tools, planters, and diggers should be cleaned and disinfected. New bags should be used, or the bags washed and disinfected. Warehouses and cellars should be disinfected by thoroughly spraying with a solution containing one pound of bluestone in ten gallons of water. Tools, machines, and bags should be disinfected with a solution of formalin containing 1 pint in 25 gallons of water.

Importance of Prompt and Correct Diagnosis

Since the symptoms of bacterial wilt and rot appear late in the growing season, are variable and often confused with those of other diseases, and the presence of late blight and insect injury make it increasingly difficult to detect diseased plants, this disease may occur for some time and even become widespread in a locality before it is definitely

recognized. Therefore, it is important that bacterial wilt be promptly and correctly diagnosed. A sharp lookout should be kept by every one for this disease. Any case found in a new locality should be verified by a microscopic examination of smears from diseased plants. In doubtful cases, specimens of vines and tubers should be sent for examination to the nearest plant pathological laboratory.

DIRECTIONS FOR MAKING SMEARS FROM VINES AND TUBERS, AND FOR COLLECTING AND MAILING SPECIMENS

The equipment needed for making smears in the field is a knife, scalpel, razor blade, or razor, alcohol, absorbent cotton, and microscope slides. The cutting instrument should be very sharp, free from nicks, and used exclusively for this purpose. The slides should be ruled in six squares with a diamond or wax pencil (Figure 3). The latter is quite satisfactory, and there is less danger of the slides breaking. A large space is kept on the left for the number of the slide or slide label, and a smaller space on the right, in order to be able to cover the field with the objective of a microscope with a mechanical stage. It is only necessary to number the slide, but the squares should always be used in the same order (Figure 3).

In making a smear from a stem, the knife is first cleaned with a wad of absorbent cotton moistened with alcohol, to make sure that there are no bacteria on the blade. The cotton is used only once. The stem is then cut two or three inches above ground, and the cut end pressed lightly against the slide inside of one of the squares. Careful notes are kept of the symptoms of the plant, locality, date, variety, and the number of the slide and smear. The knife should be cleaned immediately after making a smear.

In making smears from tubers, only slightly affected tubers should be used. A cut should be made with the clean knife at the side of the tuber, removing a thin slice (Figure 4). The knife is then cleaned, and the tuber cut across the stolon end, cutting through the freshly cut surface, and removing a thin slice at right angles to the first. Then a small piece is removed from the shoulder where part of the vascular ring is exposed, choosing an area that is discolored and suspected of harboring the bacteria (Figure 4). The end of the piece is lightly pressed against the slide inside another square.

The smears are then allowed to dry, taking care not to rub them against anything. These can be kept almost indefinitely, until the laboratory is reached, or they may be mailed for examination. Wooden

Micro slide mailing cases are the most convenient for mailing slides, as one or more slides can be mailed at one time.

The smears are fixed to the glass slide by heating until it is just too hot to bear against the back of the hand, and stained with a differential Gram stain.

The rapid Gram stain formula devised by Prof. G. B. Reed, Queen's University, Kingston, Ontario, Canada, but hitherto unpublished, is recommended for use, having given us satisfactory preparations of unusual brilliance, when tested.

Solutions: (1) Crystal Violet (or Gentian Violet)	2.5	gms.
Water	1000	cc.
(2) Sodium bicarbonate	12.5	gms.
Water	1000	cc.
(3) Iodine	20	gms.
Sodium hydroxide (Molar solution)	100	cc.
Water	900	cc.

Dissolve the iodine in the sodium hydroxide solution, and dilute with the water.

(4) Ethyl alcohol, 95 per cent	750	cc.
Acetone	250	cc.
(5) Basic Fuchsin, saturated solution in 95 per cent alcohol	100	cc.
Water	900	cc.

The solutions keep indefinitely. The procedure for staining is as follows: Flood the smear with equal parts of (1) and (2) for about 10 seconds, then drain off the excess. Flood with (3) for about 10 seconds, and then wash with water. Flood with (4) until no more color comes away, about 5 to 10 seconds, and then wash with water. Flood with (5) for not over 2 or 3 seconds, wash with water, and then dry. For immediate examination, the smears can be blotted lightly with filter paper, taking care that it does not slide over the surface. A drop of immersion oil can then be placed directly over the smear and examined under the oil immersion objective of the microscope.

The bacteria causing bacterial wilt and rot are small, short rods, 0.3-0.5 x 0.6-0.9 microns in size, and staining dark blue or black. If Gram- positive bacteria exceeding 1 micron in length are found, it is certain that these are soil-inhabiting organisms that have invaded dis-

eased tubers or stems. It should not be concluded that bacterial wilt and rot is present if only a few scattered bacteria are found in the smear. If the disease is present, the bacteria will be abundant in at least some parts of the smear.

In collecting specimens to be sent away for examination, wilted stems and slightly affected tubers should be selected. Only the lower eight inches of the stems need be sent. The base of the stem, with some of the roots attached, is best wrapped in damp, but not wet, newspaper, and then wrapping paper. The entire specimens may then be wrapped in paper and packed in a corrugated cardboard box. Only slightly affected tubers should be sent for examination; badly decayed tubers are useless. Tubers are wrapped separately, and packed in a corrugated cardboard box. Specimens should never be packed in a metal container, or in waxed paper. The specimens should be sent immediately to the institution where they are to be examined.

Attention may be drawn to the fact that in making inspections and collecting specimens, care should be exercised to avoid the contamination of shoes and clothing by coming in contact with decayed tubers, and in this manner prevent the carrying of the bacteria to other fields. The hands and knives used in handling and cutting diseased tubers should be thoroughly washed between inspections.

LITERATURE CITED

1. Savile, D. B. O. and H. N. Racicot. 1937. Bacterial wilt and rot of potatoes Sci. Agr. 17: 518-522.

THE INFLUENCE OF MATURITY OF POTATO VARIETIES UPON THEIR SUSCEPTIBILITY TO LATE BLIGHT

W. R. MILLS*

Cornell University, Ithaca, N. Y.

One of the oldest opinions in regard to late blight of potatoes, caused by *Phytophthora infestans*, to be handed down to the present generation is that young potato plants are resistant to blight and only become susceptible as they mature. This opinion is based on the common observation that ordinarily there is no serious outbreak of blight until blossoming time. There are numerous observations to this effect in the English "Gardeners' Chronicle" for 1845, the year of the

*The author takes pleasure in acknowledging his indebtedness to Professor Reddick for suggestions during the course of the work and aid in the preparation of the manuscript.

great epiphytotic in Ireland and years before the true cause of the disease was known.

Julius Kühn (7) was the first pathologist to note this apparent resistance of young plants. His observations led him to believe that there were two stages of susceptibility, the first when the plant is very young and the second about flowering time, with an intervening resistant period. In 1899, L. R. Jones (6) proposed the much-quoted theory of the "critical period" in the life of the potato plant to explain the late appearance of blight. This theory assumes that the combined activities of flowering and making tubers cause such a drain upon the vitality of the plant that it becomes particularly susceptible to disease at this time.

Since these early observations of Kühn and Jones, many experiments have been performed to test whether or not youth really confers resistance to *Phytophthora infestans*. They have largely been "time of planting" experiments in which plots are planted on successive dates about two weeks apart, and the spread of blight in these plots recorded.

The results of these experiments have been conflicting. Pethybridge (9), Crosier (3), Beaumont (1) and others have obtained results that would indicate little or no effect of age on susceptibility, whereas de Bruijn (2), Vowinckel (13) and Müller (8) conclude from their experiments that the opposite is true. Investigating the relationship between tuber formation and susceptibility, De Bruijn concluded that those varieties which develop tubers rapidly (early varieties) show a more rapid spread of blight than those with slow tuber formation (late varieties). K. O. Müller has expressed the belief that early varieties appear to be more susceptible than late ones because they arrive at that state of maturity in which an attack is possible at an earlier date.

The object of the following experiments was either to prove or disprove the theory that potato plants are more susceptible to late blight during tuber formation than previous to this period. Since other workers have obtained contradicting evidence, the problem was approached from a slightly different angle than time of planting.

It is well known that the tuber set of late varieties of potatoes is more or less dependent upon the length of day. Garner and Allard (5) have shown, with the variety McCormick, that a very long daylight period tends to direct the activities of the plant toward vegetative development to the exclusion of tuber set. Schick (11), Tincker (12) and others have reported the same reaction. Tincker noted some

varietal differences in the reaction to length of day, but in general he found the ratio of tops to tubers to be about seven times as high at thirteen hours as at ten hours.

The method followed, then, was to induce age artificially in one set of plants by shortening the period of daylight received, whereas a corresponding set received normal daylight of thirteen to fourteen hours. It was thought that this might give a more accurate comparison of true physiological age than planting at intervals, since there is in most late varieties the tendency toward continued vegetative growth until the required length of day is reached for tuber formation, regardless of the length of time the plant has been growing. Tubers were planted in pots in the greenhouse about the first of March. About a month later, when the plants were well above ground, they were divided into two sets and moved into ventilated glass chambers. One set received normal daylight whereas the other was darkened with a heavy black cloth every afternoon at five o'clock and opened in the morning at eight, thus receiving nine hours of daylight. The plants were inoculated by placing a drop of a swarm spore suspension of *P. infestans* on the very tip of a leaflet, the terminal and first pair of leaflets being used. The rate of spread of the fungus through the leaf tissue was determined by measuring the length of the lesion along the midrib. The progress of the fungus was fairly constant and the limits of the infected area could easily be determined by holding the leaflet to the light and measuring from the lower surface.

As originally planned, successive inoculations were to be made about two weeks apart on each plant until the short-day plants had reached maturity. Several difficulties prevented the completion of these experiments. In the first place, only a few leaflets of each plant could be inoculated at one time, because of the necessity of reserving material for future trials. In addition, to secure exact measurements of the progress of the fungus through the leaflet, it was necessary to inoculate the leaflet at the very tip. It seemed to be impossible to prevent some of these drops from running off onto the stems and petioles beneath, the resulting infections killing the plants. On another occasion the greenhouse temperature fell sufficiently low to allow natural infection to occur. However, in one case two successive inoculations were recorded. In this experiment the first inoculation was made after one set of plants had been subjected to short day for fifteen days, the other receiving normal (April) daylight.

The second inoculation was made eighteen days later. Briefly summarized, the results are:

	Mean Lengths of Lesions in Millimeters Nine Days after Inoculation	
	1st Inoculation	2d Inoculation
Short Day	31.6	29.6
Long Day	34.1	30.2

From 30 to 40 leaflets were used in each test.

Both sets of plants appeared slightly less susceptible at the second than at the first inoculation. However, no significance can be attached to this, since it has been shown (Crosier:3) that the rate of spread of the fungus through the leaf tissues increases with increased temperature, to approximately 23° C. Since the greenhouse temperatures were not closely controlled the only legitimate comparison is between long- and short-day plants of the same inoculation. In both inoculations the long-day plants were slightly more susceptible, but the differences are too small to be significant.

In the following experiment no attempt was made to make successive inoculations. Six pots of each of the following varieties were planted on the 6th of March, 1935: Bliss Triumph, Green Mountain, Katahdin, Smooth Rural and 215-34, an unnamed variety resulting from a cross between Evergreen and Ekishirazu. These varieties were chosen because of their known reactions to length of day. The very early variety Bliss Triumph is indifferent to length of day, as it will set tubers in either long or short daylight periods. Green Mountain and Katahdin are of the intermediate class, making some tubers in periods of long daylight, but definitely preferring shorter hours. Rural will scarcely make tubers in June, whereas 215-34, a very much later variety, positively requires a short day for any tuber formation.

On the 28th of March when the plants were four or five inches tall they were divided into two sets, and moved into the glass chambers where three plants of each variety received normal daylight* and three nine hours daily. All plants were inoculated on the eve-

*The lengths of days, calculated from sunrise to sunset, for March 28 to June 16, vary from 12.5 to 15.2 hours.

ning of the 16th of June and the next morning they were all moved to a greenhouse bench to insure equal conditions of temperature and humidity for the development of the disease. Measurements were made nine days after the inoculation.

An examination of table 1 shows that in no cases were any of the short-day plants significantly more susceptible than the long-day plants. In the case of Rural, the odds are about 400:1 that the long-day plants were more susceptible, whereas no other difference is large enough to be statistically significant.

TABLE 1—*Comparison of susceptibility of short day versus long day plants*

Length of Day	Varieties				
	Triumph	Green Mountain	Katahdin	Smooth Rural	215-34
Short Day	37.6±0.57 (27)*	36.2±0.56 (39)	34.8±0.78 (24)	34.3±0.69 (34)	31.2±0.72 (6)
Long Day	36.4±0.73 (41)	35.2±0.89 (37)	34.8±0.82 (30)	38.6±0.67 (43)	34.9±1.40 (9)
Dif.	1.2±0.93	1.0±1.05	0.0	4.3±0.96	3.7±1.57
D/PE	1.29	0.95	0	4.48	2.36

*Figures in parenthesis are the numbers of infected leaflets measured.

It may be noted that Triumph is slightly more susceptible than the other varieties, with the exception of the long-day Rurals. As previously mentioned, the claim has been made that early varieties are more susceptible to blight than late ones, simply because they mature earlier and therefore reach the susceptible stage at an earlier period than the late varieties. If such is the case, one would then expect to find a difference in susceptibility between a mature Triumph and an immature late variety which would disappear as the late sort attained a state of maturity corresponding to that of the Triumph. In other words, when the late variety reaches the same state of maturity as the Triumph, it should be just as susceptible. It is obvious from these data that there was no such leveling off since no variety, including Triumph, became more susceptible with age. Any differences between mature Triumph and other varieties that were immature were either maintained or actually increased as the late varieties matured.

Discussion

It is fully realized that these experiments have not been conducted under strictly natural conditions, inasmuch as "age" has been artificially induced. However, the short-day (old) plants had every appearance of natural age. They had ceased all apical growth and were setting tubers heavily at the time of inoculation. The long-day (young) plants were nearly twice the size of the short-day plants and growing vigorously. Both long- and short-day Triumph plants were tubering heavily, but the long-day plants were considerably larger and had a heavier set of tubers.

The selection 215-34 was included in this test not only because of its lateness, but also because of the considerable resistance to blight which it had shown in the field. It may be noted from the table that very few infections resulted from the inoculations of this variety, although the plants were about as large as the other varieties and had approximately the same number of leaves inoculated. Reddick (10) has pointed out that resistance to *Phytophthora* may be expressed not only by the progress of the lesion but also by resistance to penetration. Apparently this variety possesses resistance to penetration as well as some resistance to spread within the leaf tissue, as compared with the other varieties in the experiment. Since the inoculations of all the varieties except Green Mountain resulted in more infections of the long-day plants than of the short-day ones, it might be assumed that the short-day plants were showing some resistance to penetration. Actually, this difference was because of the number of leaflets inoculated, since the long-day plants were considerably larger than the short-day ones.

Under the conditions of these experiments it can only be concluded that maturity has not increased the susceptibility of the varieties tested, whereas the only significant change observed was Rural becoming less susceptible with age. In routine inoculation and testing of varieties, it has often been observed that small plants just coming through the soil are likely to be difficult to infect, because of the large number of hairs per unit area of leaf surface. These hairs cause the inoculation drops to spread out immediately and run off the leaf, drying out before penetration can take place. This is a mechanical action that has no bearing upon any protoplasmic change which might occur as the plant matures.

Conclusions drawn from "time of planting" experiments have largely been based upon counts of blighted plants or leaves within the

plot rather than upon the actual rate of spread of the fungus through the leaf tissue. Beaumont (1) has pointed out that in plots of different ages there exists a difference in what he terms "epidemic potentiality." The primary foci are liable to be more numerous in old plants, since they have had more ttime to develop, with a greater secondary infection around these primary foci. Extensive observations and experiments by Crosier and Reddick (4) and Crosier (3) have proven the absolute necessity of correct conditions of temperature and humidity for the occurrence and spread of blight in plants of any age. They have shown that a relative humidity of 95 per cent or above must exist for a minimum of eleven or twelve hours to permit sporulation of the fungus, germination of the sporangia and penetration of the leaf tissue and for at least two hours the temperature must be around 11° C. to permit swarm spore formation.

The role of heavy foliage of old plants which covers the ground cannot be emphasized too strongly in its effect in maintaining this necessary condition of high humidity. One has only to examine such plants to be convinced of their efficacy. Many times the author has noted plants of this nature lying upon the ground wet with dew at 11 o'clock in the morning, whereas small plants in the same plots were dry at 8 o'clock. Considering these necessary conditions for the occurrence and spread of blight, it is easily understood why blight may be prevalent in "old" plants which are "down" and spread all over the ground, while "young" plants—small and erect—may be free from blight.

SUMMARY

Artificially induced maturity of five varieties of potatoes did not increase susceptibility to *Phytophthora infestans*. The only significant change observed was decreased susceptibility of mature Smooth Rural plants.

LITERATURE CITED

1. Beaumont, A. 1934. On the relation between the stage of development of the potato crop and the incidence of blight (*Phytophthora infestans*). Ann. Appl. Biol. 21: 23-47.
2. Bruijn, Helena L. G. de. 1926. Waarnemingen over de vatbaarheid van het loof van de aardappelplant voor de aardappelziekte. Tijdschr. Plantenziekten 32: 1-29. (English summary).
3. Crosier, Willard. 1934. Studies in the biology of *Phytophthora infestans* (Mont.) de Bary. Cornell Univ. Agr. Exp. Sta. Memoir 155: 1-40.
4. Crosier, Willard and Donald Reddick. 1935. Some ecologic relations of the potato and its chief fungous parasite, *Phytophthora infestans*. Amer. Potato Jour. 12: 205-219.
5. Garner, W. and H. A. Allard. 1923. Further studies in photoperiodism, and

response of the plant to relative length of day and night. Jour. Agr. Res. 23: 871-920.
6. Jones, L. R. 1899. Certain potato diseases and their remedies. Vt. Agr. Exp. Sta. Bul. 72: 3-32.
7. Kühn, J. 1880. Bericht über Versuche zur Prüfung des Gülichschen Verfahrens beim Anbau der Kartoffeln. Bericht aus dem phys. Lab. u. Versuchsanst. Landwirtschaft. Inst. Univ. Halle 1: 1-100.
8. Müller, K. O. 1928. Uber die Züchtung krautfauleresistenter Kartoffel sorten. Zeitschr. Pflanzenücht. *13*(3): 143-156.
9. Pethybridge, G. H. 1910. Potato diseases in Ireland. Dept. Agr. and Tech. Instr. Ireland Jour. 10: 241-256.
10. Reddick, Donald. 1928. Blight-resistant potatoes. Phytopath. 18: 483-502.
11. Schick, R. 1931. Der einfluss der Tageslänge auf die Knollenbildung der Kartoffel. Der Züchter 31: 356-369.
12. Tincker, M. A. H. 1925. The effect of length of day upon the growth and reproduction of some economic plants. Ann. Bot. 39: 721-754.
13. Vowinckel, Otto. 1926. Die Anfälligkeit deutscher Kartoffelsorten gegenüber *Phytophthora infestans* (Mont.) de By., unter besonderer Berücksichtigung der Untersuchungsmethoden. Biol. Reichsanst. Landu. Forstw., Arb. 14: 588-641.

SOIL REACTION IN RELATION TO POTATO SCAB

R. H. Larson, A. R. Albert and J. C. Walker

Wisconsin Agricultural Experiment Station, Madison, Wis.

The influence of soil reaction (pH) upon the natural occurrence of common potato scab (*Actinomyces scabies* (Thax.) Güssow) has been studied in many localities and on numerous soil types. Dippenaar (2) has carefully reviewed the literature on the subject up to 1932. Most attention has been given to the acid range of soil reaction and there is a general agreement among workers that as the soil pH decreases beyond approximately 5.2 an appreciable reduction in the incidence of the disease occurs. This fact is of inestimable value to potato growers in many regions particularly along the Atlantic seaboard from Maine to Florida where cultural practices designed to maintain a highly acid soil relegate potato scab to a relatively minor position. There are many soils in the Great Lakes region of limestone origin in which the natural reaction is sufficiently less acid to be very favorable for scab development; in other soils although the natural reaction is about pH 5.0 the scheme of farming being practiced calls for the addition of some type of lime to facilitate the production of legumes either for forage or green manure.

In 1936 Smith (4) secured a reduction in scab infection in Western New York by increasing the alkalinity of Dunkirk silty clay loam to pH 7.16-7.45. Continued cropping with potatoes (Smooth

Rural) was followed during the next four years. No significant reduction in scab was shown in 1933 as the alkalinity increased to a pH of 7.41 to 7.80, but a significant reduction in the incidence of scab occurred at a pH 7.95-8.27. In 1934 scab increased in plots with a soil reaction up to pH 6.93-6.94 and decreased from 85.1 per cent (by weight) at that point to 68.6 and 62.3 per cent, respectively, at pH 7.53-8.21 and pH 8.23-8.36. In 1935 scab increased with alkalinity to 36.6 per cent at pH 7.23-7.34, and decreased to 25.7 per cent at pH 8.01-8.18, and 5.9 per cent at pH 8.18-8.43. In 1936 scab was greatest at pH 6.23-6.71 (82.9 per cent) decreasing to 62.2 per cent at pH 6.76-7.04, 42.5 per cent at pH 7.14-7.60 and 27.0 per cent at pH 7.80-7.92. Surveys by Blodgett and Howe (1) in Western New York and by Goss (3) in Western Nebraska have shown a decrease in scab incidence in alkaline soils.

The importance of the control of potato scab through increased soil alkalinity, if possible and practicable, is obviously great in many localities and in certain types of farm management. The writers present herewith the results from a series of field plots in Wisconsin on which this question was studied during the seasons of 1935, 1936, and 1937.*

LOCATION AND TREATMENT OF PLOTS

Plots were laid out on three types of soil each located in a different region of the state. At Antigo in northern Wisconsin the soil was Antigo silt loam typical of one of the most productive potato areas of the state. At Arnott (near Stevens Point) in central Wisconsin the soil was Plainfield sandy loam characteristic of a large but less productive area in which the soils are usually about pH 5.0. At Delavan a muck soil was used which is typical of the peat lands of southeastern Wisconsin occurring in a limestone area; these soils are usually moderately acid.

The soil reaction was adjusted in each location to approach the desired range by the addition of sulphur or lime. At Antigo and Arnott inoculated sulphur was used whereas at Delavan 100-mesh commercial flours of sulphur was applied. The type of lime used was determined by that available for general use in the locality, Antigo hydrated lime; whereas at Arnott and Delavan finely ground dolomitic was used. The initial treatments were made at Antigo and

*This investigation was supported in part by the Federal Works Progress Administration.

Arnott in the spring of 1935 and at Delavan in the autumn of 1935. All types of lime were applied broadcast and disked in thoroughly. Certain supplementary treatments were made as needed. The plots at Antigo and Arnott were 36 by 50 feet; and at Delavan slightly larger. The treatments and pH readings during the three years are given in table 1.

TABLE 1—*Scab treatment reaction (pH) and scab index in Wisconsin potato soils*

Plot Number	Material Applied (Lbs. per Acre)	Reaction (pH) Before Treatment	Reaction (pH) Harvest 1935	Reaction (pH) Harvest 1936	Reaction (pH) Harvest 1937	Scab Index 1935	Scab Index 1936	Scab Index 1937
	ANTIGO (NORTHERN WISCONSIN)—ANTIGO SILT LOAM							
	(Spring, 1935)							
71	9000 $Ca(OH)_2$ a/	6.1	8.0	7.8	7.5	99.0	99.3	No test
72	6000 " b/	5.9	7.5	7.5	7.3	99.2	98.7	"
73	3000 "	6.3	6.8	6.2	6.4	99.0	96.8	"
74	None	6.1	6.0	6.0	5.8	97.9	92.0	"
75	1000 Sulphur	6.0	5.5	5.3	5.5	76.7	75.0	"
76	2000 "	6.0	4.4	4.8	5.4	59.5	65.0	"
77	3000 "	6.1	4.1	4.3	4.8	54.2	49.1	"
	ARNOTT (CENTRAL WISCONSIN)—PLAINFIELD SANDY LOAM							
	(Spring, 1935)							
17	9000 $CaCO_3$ c/	5.3	6.1	6.5	7.0	53.0	84.0	No test
16	7000 $CaCO_3$	5.2	6.0	6.5	6.6	48.0	92.7	"
15	5000 "	5.3	5.5	5.4	5.4	41.7	67.3	"
14	3000 "	4.9	5.3	5.7	6.0	50.0	66.7	"
13	1000	4.9	5.4	5.0	5.5	62.0	61.3	"
12	None	5.2	5.0	4.6	4.8	61.3	60.0	"
11	700 Sulphur	5.0	4.5	4.6	4.1	58.7	45.7	"
	DELAVAN (SOUTHERN WISCONSIN)—MUCK							
	(Fall, 1935)							
1	16,000 $CaCO_3$	6.0	No test	6.5	6.8	No test	91.7	90.9
2	10,000 "	6.0	"	6.1	6.5	"	90.0	92.5
3	8,000 "	6.0	"	6.1	6.5	"	83.7	92.3
4	6,000 "	6.0	"	6.1	6.3	"	73.3	93.2
5	None	6.0	"	6.0	6.0	"	72.7	86.9
6	1,200 Sulphur	6.0	"	5.4	5.5	"	51.3	62.4
7	2,400 "	6.0	"	4.5	5.0	"	50.0	52.1

a/ Plus 2000 lbs. of Na_2CO_3 spring of 1936; b/ Plus 1000 lbs. of $Ca(OH)_2$ spring 1936.

c/ Plus 3600 lbs. $CaCO_3$ spring of 1936.

METHOD OF RECORDING SCAB

The method of recording scab in all treatments at the three stations was the same as used in the studies of scab resistance by Walker, Larson, and Albert (5). The scab susceptible variety, Irish Cobbler, was used in all the test plots except at Arnott in 1936 where the Katahdin which was equally susceptible to scab was used.

Experimental Results

Antigo Trials

The reaction of the Antigo silt loam adjusted to new levels promptly. It may be seen in table 1 that during the 1935 season, following spring treatment, a wide range from very acid to highly alkaline reaction was secured. The soil was naturally very heavily infested with the scab organism and a high scab index occurred during both years in the untreated plot. Scab was reduced consistently with a decrease in pH in the three sulphur plots and this condition was maintained without further sulphur treatment in 1936. Increase in pH up to 8.0 did not reduce the scab index in either 1935 or 1936. On the plot receiving the largest amount of lime, 2,000 pounds of sodium carbonate were added to the acre in 1936 to increase the pH if possible. No change occurred, however, and the limed plots gave essentially the same scab index in 1936 when replanted without further treatment except for the addition of commercial fertilizer.

Arnott Trials

In the Plainfield sandy loam, where ground limestone was used, the adjustment of soil reaction was very much slower, although the pH readings at the end of the 1935 season showed a change in the expected direction. The shift in soil reaction during the season, determined by monthly readings, showed that these changes occurred too slowly to affect the scab incidence during tuber set in 1935. The difference in scab index between treated and untreated plots was not significant.

At harvest time in 1936 the plots showed a range in reaction from pH 4.6 to 6.5. The addition of sulphur increased acidity slightly and a decided reduction in scab index resulted. Increments of limestone to a maximum of 5,000 pounds to each acre increased the pH slightly but in plot 15 (5,000 pounds on each acre) it was only pH 5.4 and the scab index only a small amount larger than that of the check. For the successful growing of such legumes as alfalfa this reaction is

ordinarily regarded as too acid. This crop would normally require an application of 7,000 pounds of lime to the acre on this type of soil. Such a treatment was made in plot 16 where the pH increased to 6.5 by the harvest of 1936 and the reaction had changed little at the end of the 1937 season. The most heavily limed plot (plot 17) was similar to plot 16 during 1935 and 1936 but had increased to pH 7.0 by harvest of 1937. In these two plots there was a very significant increase in the scab index. It is obvious that moderate liming of this sandy soil might not seriously increase scab but sufficient amounts to suffice for certain legumes are instrumental in increasing scab incidence upon tubers of scab-susceptible potato varieties.

Delavan Trials

In the muck soil there was a prompt increase in acidity after the sulphur applications but very slight increases in alkalinity after very large amounts of ground limestone, the change in pH being not more than 0.5. However, a progressive increase in scab index followed increasing amounts of lime and a decrease followed increasing amounts of sulphur. The same condition was maintained without further treatment in 1937. It is obvious that in this soil a decided improvement in the appearance of the crop could be secured by applications of a ton of sulphur to the acre.

Discussion

The general trend of results from the treatments reported on scab-infested soils in Wisconsin confirm many previous observations that the disease is reduced with increasing acidity. It is to be noted, however, that in no case was scab eliminated when the pH was held below 5.0 even for a two-year period. Whereas the results of Dippenaar (2) secured in some of the same locations gave no significant control with applications of sulphur in the row, it is amply demonstrated in these tests that when a broadcast application is worked in thoroughly, applications of sulphur consistently reduced scab in these three widely different soil types.

At no time was there any indication of reduction in scab by application of lime even in amounts beyond those which would be economically profitable. It is true that in most cases the alkalinity did not reach a point comparable to those cited by others (1, 3, 4) in which a reduction in scab incidence was found. In the case of plot 71 at Antigo the same range of pH was secured at which Smith (4)

noted scab reduction but such did not occur in this plot. It appears that very heavy liming, however desirable it may be for certain legumes, cannot be depended upon to reduce scab incidence sufficiently to warrant its use for that sole purpose.

Probably the use of sulphur has limited application in Wisconsin. The cost is possibly too great for use on southern Wisconsin muck. In central Wisconsin it should seldom be required unless heavy liming has been practiced. Where the growing of lime-loving legumes is unimportant, the best procedure for potatoes in this area may be to use soil which has not been limed or, if so, only lightly. The use of sulphur on this soil at a pH 5.0 or 5.2 is likely to be detrimental to some crops. In the Antigo area where intensive potato production prevails it is obvious that the application of lime is dangerous for potatoes. Where very scabby spots of limited area occur, the use of sulphur in amounts sufficient to reduce the pH to 5.2 or 5.0 may be a satisfactory procedure.

The application of lime carbonate in some form is quite generally accepted as good practice on farms where lime-loving legumes are grown. The intensive production of any one crop without rotation, or in very short rotations, is often followed by numerous difficulties. It is accordingly questionable whether any soil intended for the regular production of crops in rotation should be subjected to a drastic reduction of reaction by means of sulphur unless, and until, the whole scheme of farming can be adjusted to very acid soil conditions. The secondary effects of liming are far better known than those of "sulphuring" insofar as crops other than potatoes are concerned. The secondary, or indirect effects of liming on potato scab incidence as well as the effects of "sulphuring" on other crops are being studied by the authors. Insofar as potato yields are concerned there were no marked effects on the latter from any of the treatments described.

LITERATURE CITED

1. Blodgett, F. M., and Howe, F. B. 1934. Factors influencing the occurrence of potato scab in New York. Cornell Univ. Agr. Exp. Sta. Bull. 581.
2. Dippenaar, B. J. 1933. Environmental and control studies of the common scab disease of potatoes caused by *Actinomyces scabies* (Thaxt.) Guss. Dept. of Agr. Union of South Africa Science Bull. No. 136. Science Series No. 17.
3. Goss, R. W. 1934. A survey of potato scab and Fusarium wilt in Western Nebraska. Phytopath. 24: 517-527.
4. Smith, Ora. 1936. Effect of soil reaction on growth, yield, and market quality of potatoes. Cornell Univ. Agr. Exp. Sta. Bull. 664.
5. Walker, J. C., Larson, R. H., and Albert, A. R. 1937. Studies of resistance to potato scab in Wisconsin. Amer. Potato Jour. 15:246-252.

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